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Effect of the Pittsburgh Air Pollution Episode Upon Pulmonary Function in School Children

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16. ABSTRACT

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EFFECT OF THE PITTSBURGH AIR POLLUTION EPISODE UPON PULMONARY FUNCTION IN SCHOOLCHILDREN

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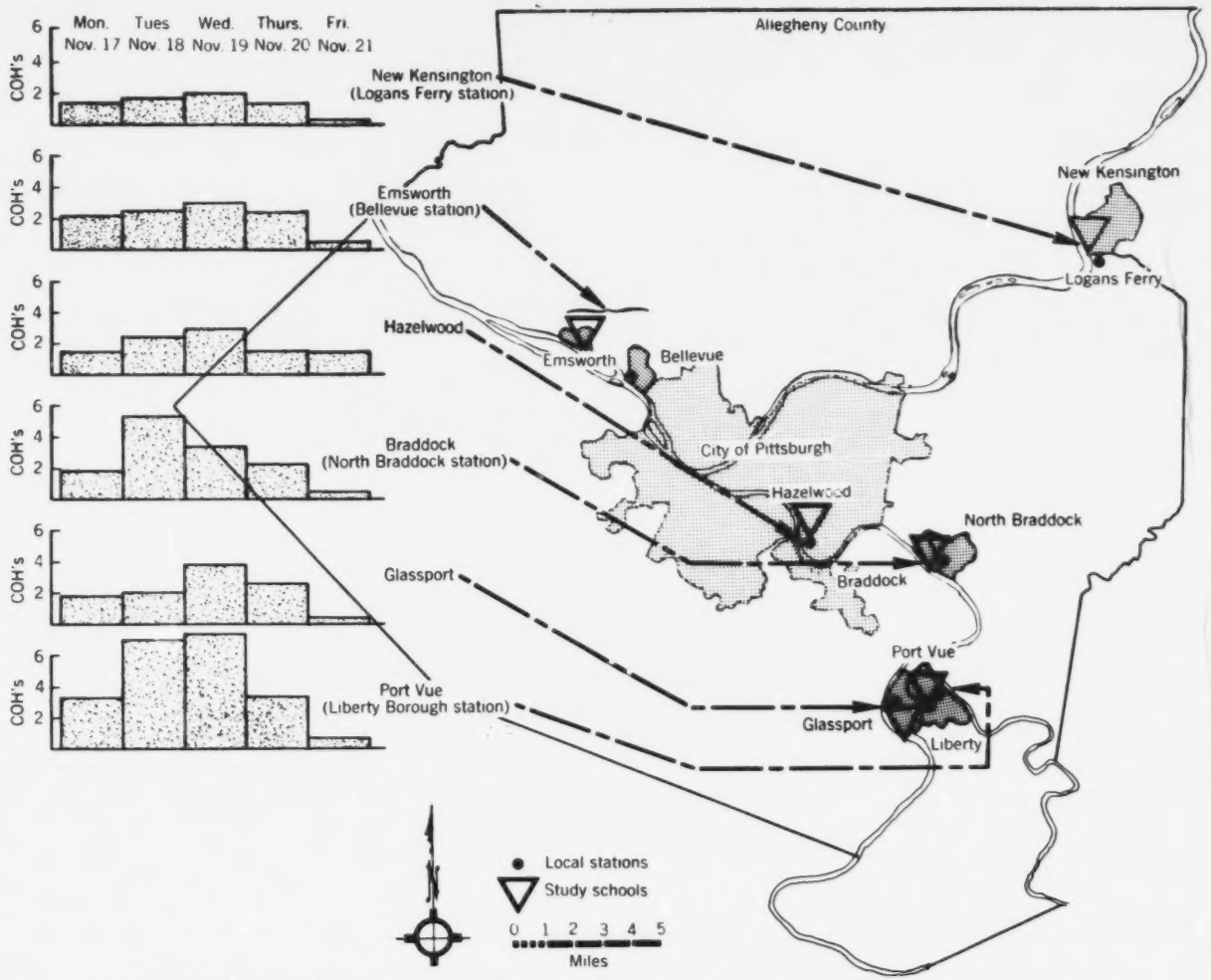

Figure 1. Particulate levels (24 hr COH's) during air stagnation advisory of 17–21 November, 1975, Allegheny County, PA.

Shortly before noon on Wednesday, November 19, 1975, the staff of the Population Studies Division, Health Effects Research Laboratory, Environmental Protection Agency (EPA), was informed of the existence of an air pollution episode in Pittsburgh. Tentative preparations for a study of the health effects were made, and the decision to proceed was finalized at 8 P.M., November 19. Data collection began November 20, but was not in full swing until November 21. Since considerable publicity attended the execution of the study, and even more publicity attended the news report of results at the end of December, it is felt that a detailed, though still preliminary, report is owed the air pollution control community.

The hypothesis tested was: Did exposure to emergency stage particulate pollutants so severely impair the breathing capacity of primary school children that it would take their lungs several days to recover? This hypothesis was selected because an objective index of impairment, the three-quarter second forced expiratory volume ($FEV_{.75}$) recorded on a spirometer, was preferred to symptoms recorded on interview while the episode was a major news item. The study was so designed that one would expect, if the air pollution had impaired lung function severely, that the observed values of $FEV_{.75}$ would trend upward over the study period in those school children exposed to heavy pollution, but would remain more or less the same in the control school children.

Methods

The study areas were Roman Catholic parishes in which were located the parochial schools nearest 6 of 7 automated Allegheny County air monitoring sites (downtown excluded). Figure 1 shows the locations of both schools and stations. New Kensington and Emsworth were considered control areas, Hazelwood, Braddock, and Glassport high exposure areas, and Port Vue was closest to Allegheny County's Liberty Borough monitoring site which recorded the highest pollution levels during the emergency. The Emsworth school replaced a school nearer the sampling site which refused cooperation. Catholic schools were selected because of ease in getting diocesan permission, while there were numerous public school boards to be dealt with.

To minimize confounding of learning effects with real improvements, older children are preferred subjects; to maximize assumed sensitivity, younger children are preferred. As a compromise, the fourth grade classes were selected, then fifth, then sixth, until approximately fifty children were tested. The same children were tested each morning through November 26 (the day before Thanksgiving), including the weekend. Most subjects in Hazelwood were tested November 20, as was one class in New Kensington. Otherwise testing began November 21. Grades and total numbers of children tested at least once were:

New Kensington, 4–6 and 43; Emsworth, 4–5 and 37; Hazelwood, 4–5 and 40; Braddock, 4–5 and 54; Glassport, 4–5 and 44; and Port Vue, 4–6 and 54. A total of 272 children was tested. Absenteeism rates were not excessive on November 20 and 21, so the children available for testing on those days were not significantly selected for resistance to effects of pollution. The very rare asthmatic and nonwhite children have not been excluded from this analysis.

Including the first test, which defined the study population, 89% of possible tests were carried out. Response rates even on Saturday and Sunday were much higher than expected (rates for New Kensington, Emsworth, Hazelwood, Braddock, Glassport, and Port Vue were on Saturday 33, 73, 53, 87, 73, and 81%, and on Sunday 79, 73, 50, 63, 64, and 80%.) Only one refusal by a parent was encountered. The study protocol called for the same technician to test a child each day using the same spirometer so that technician and instrument effects would not be confounded with pollution effects. Two breaches of this protocol occurred: two of three classes in Port Vue were tested November 21 by a technician not otherwise used, and in New Kensington, because of mechanical difficulties, a new spirometer was used beginning part way through testing November 21. Neither of these two breaches of protocol affects conclusions drawn in this preliminary analysis. In four schools 50% of the children were retested at random the first day in an attempt to estimate a learning effect. These data, when analysed, will also not affect the conclusions drawn here.

The $FEV_{.75}$ and the forced vital capacity (FVC) were recorded for three satisfactory expirations. For analysis the maximum of the three was chosen and converted to a body temperature, ambient pressure, saturated volume. With one exception tests were done with the subjects standing, using a 12 liter dry-seal bellows-type spirometer manufactured by Cardio-Pulmonary Instruments, Inc., routinely used by EPA.[1] The linearity of the digital readout was checked each day and before each class to insure that it remained within 1% of the mechanical readout over the range of anticipated volumes. Spirometer temperatures were recorded before and after testing each class, and usually when testing each child on the weekend. In Hazelwood a 10 liter Collins Steadwell water-filled spirometer was used, subjects were tested seated and wearing a noseclip, and inhalation took place through the mouthpiece. The technicians in Hazelwood and Port Vue had had extensive experience in using their spirometers, the technician in New Kensington had had some limited experience with hers and was otherwise experienced in field epidemiology, and the remaining technicians were student respiratory therapists who had had extensive experience with sophisticated respiratory laboratory equipment (and with patients) and who handled the CPI instruments, after one training session, with no difficulty. In short, the technicians were *not* quickly trained laymen. The recorders, to whom the technicians called off numbers, were in a few instances laymen, and did change from day to day.

Statistical analysis of the pulmonary function data was carried out using a general linear model, described by Graybill,[2] and implemented through the SAS statistical analysis system.[3] Analyses were carried out separately for each school; terms corresponding to each child tested and each date on which tests were carried out were incorporated into the linear model. The model estimates child and day effects; from these the means for each date were computed, adjusting for the specific children tested on a given date. This adjustment is essential because of the nonresponse on the crucial weekend days. Daily or overall means cannot be compared

Table I. Particulate levels (COH) in Allegheny County, PA, 17–26 November 1975.

	November									
	17th		18th		19th		20th		21st	
Air stagnation advisory	24 hour	Max hourly	24 hour	Max hourly	24 hour	Max hourly	24 hour	Max hourly	24 hour	Max hourly
New Kensington (Logans Ferry)	1.37	*3.47*	1.69	*3.60*	1.95	*3.39*	1.26	*3.60*	0.32	*0.46*
Emsworth (Bellevue)	2.11	*4.36*	2.51	*3.94*	2.99	*5.11*	2.39	*4.41*	0.53	*1.12*
Hazelwood	1.53	*4.48*	2.39	*5.34*	2.90	*5.79*	1.76	*4.15*	1.74	*4.58*
Braddock (North Braddock)	1.78	*6.01*	5.24	*10.26*	3.34	*6.10*	2.27	*4.09*	0.52	*1.10*
Glassport	1.81	*4.30*	2.02	*4.39*	3.74	*8.72*	2.56	*5.43*	0.43	*0.97*
Port Vue (Liberty Borough)	3.33	*10.13*	6.99	*10.85*	7.37	*10.51*	3.42	*7.59*	0.67	*2.67*
Lung function study continued	22nd		23rd		24th		25th		26th	
New Kensington (Logans Ferry)	0.36	*1.11*	0.95	*1.45*	1.28	*2.06*	0.69	*1.10*	0.65	*1.46*
Emsworth (Bellevue)	0.83	*1.76*	1.64	*2.58*	1.81	*3.30*	0.84	*1.79*	0.94	*1.58*
Hazelwood	1.34	*4.25*	1.11	*2.60*	1.42	*3.53*	1.04	*3.78*	0.73	*2.03*
Braddock (North Braddock)	0.49	*0.97*	1.88	*3.80*	1.44	*2.33*	0.70	*1.40*	0.80	*1.34*
Glassport	0.39	*0.88*	1.66	*2.51*	2.13	*4.37*	0.71	*1.63*	0.75	*1.74*
Port Vue (Liberty Borough)	0.43	*1.56*	2.91	*6.50*	1.89	*3.35*	0.97	*2.38*	0.72	*1.15*

Table II. Sulfur dioxide levels (ppm) in Allegheny Co., PA. 17–26 November 1975.

	November									
	17th		18th		19th		20th		21st	
Air stagnation advisory	24 hour	Max hourly	24 hour	Max hourly	24 hour	Max hourly	24 hour	Max hourly	24 hour	Max hourly
New Kensington (Logans Ferry)	.055	*.194*	.061	*.161*	.048	*.108*	.030	*.063*	.040	*.072*
Emsworth (Bellevue)	.023	*.043*	.026	*.054*	.036	*.085*	.023	*.048*	.016	*.030*
Hazelwood	.084	*.272*	.125	*.410*	.130	*.402*	.078	*.275*	.112	*.259*
Braddock (North Braddock)	.098	*.204*	.118	*.249*	.090	*.135*	.056	*.114*	.033	*.112*
Glassport	.025	*.063*	.025	*.087*	.045	*.128*	.028	*.060*	.015	*.039*
Port Vue (Liberty Borough)	.101	*.259*	.073	*.310*	.047	*.085*	.031	*.091*	.015	*.055*
Lung function study continued	**22nd**		**23rd**		**24th**		**25th**		**26th**	
New Kensington (Logans Ferry)	.025	*.080*	.060	*.217*	.034	*.063*	.064	*.099*	.042	*.074*
Emsworth (Bellevue)	.015	*.025*	.028	*.054*	.025	*.055*	.023	*.042*	.022	*.053*
Hazelwood	.086	*.295*	.056	*.196*	.039	*.104*	.083	*.268*	.052	*.160*
Braddock (North Braddock)	.030	*.043*	.087	*.201*	.045	*.125*	.056	*.102*	.054	*.142*
Glassport	—	—	—	—	—	—	.014	*.030*	.019	*.060*
Port Vue (Liberty Borough)	.014	*.036*	.052	*.073*	.030	*.092*	—	—	.026	*.071*

among schools since adjustments have not been made for differences in classes tested, or for height, age, or sex. These adjustments for between school comparisons are not relevant to the hypothesis being investigated. (Within each school, the adjustment of each daily mean for the specific children tested automatically adjusts each daily mean for daily differences in the mean age, height, sex, or class of the children tested.)

For purposes of graphic and tabular presentation the study areas are ordered according to the maximum hourly values of particulates (COH) on November 19, the peak of the episode.

Air Pollution Measurement

Pittsburgh was located near the center of an anticyclone which caused an Air Stagnation Advisory to be issued at noon, Monday, November 17, 1975, for Western Pennsylvania and portions of Ohio and West Virginia by the National Weather Service. At noon on Thursday, November 20, a Termination of Air Stagnation Advisory was issued to take effect at 0600 hr, Friday, November 21. Emergency levels of air pollution did occur in portions of Allegheny County during this period.

The Allegheny County Health Department had declared a countywide air pollution watch at 2100 hr November 16, based on current meteorological and air monitoring data. At the same time a first stage alert was declared for the Liberty Borough area. Of the remaining monitoring areas a first stage alert was declared in all but two on November 18. For the Liberty Borough area the second stage alert was called at 0400 hr November 19, and the emergency was declared for that area at 1430 hr November 19. The emergency was lifted at 1400 hr November 20, and at 2200 hr on November 20 all alerts and the air pollution watch were terminated.

Air pollution data from the 6 of 7 automated sites (the downtown station being excluded) near which the lung function study was carried out were obtained from the Bureau of Air Pollution Control, Allegheny County Health Department. Numerical data were obtained for sulfur dioxide (SO_2), coefficient of haze (COH), and total suspended particulates (TSP); filter strips were obtained for suspended sulfate (SS) and nitrate (SN) determinations.

Sulfur dioxide measurements were obtained using Philips Electronic Instruments, Model PW 9700, an amperometric (coulometric) technique which utilizes bromine titration.[4]

Coefficient of Haze (COH) or Soiling Index measurements were made using a modified Unico Model 2800 instrument which utilizes a paper filter tape through which air is drawn. The optical density of the resulting soiled spot is measured by comparison of the transmittance of the spot with that of a clean section of the same filter paper.[5] For the seven automated Allegheny County monitoring sites as a group one COH is generally considered equal to 1.5×10^2 $\mu g/m^3$ (±30%) of TSP; the conversion factor for the Liberty Borough site itself

appears to be approximately 1×10^2 $\mu g/m^3$.[6]

Mass measurements of TSP were made by the Allegheny County Health Department from samples obtained using Unico high volume samplers. Suspended sulfate and suspended nitrate concentrations were determined by EPA using strips of the Allegheny County filters. Automated chemical analyses on those 191 mm strips of glass fiber filter were carried out by the EPA contractor currently responsible for routine analysis of samples from the Community Health Air Monitoring Program. Methods used were methythymol blue for SS and copper-cadmium reduction for SN.[7]

Figure 1 shows the relative levels and the locations of the 24 hr mean COH levels during the period of the Advisory; numerical COH values during the Advisory and for the later days on which lung function testing was being carried out are presented in Table I. In the most highly polluted area, Liberty Borough, levels corresponded roughly to 700 $\mu g/m^3$ (24 hr) and 1100 $\mu g/m^3$ (maximum hourly) of TSP at their peak. Corresponding SO_2 levels are shown in Table II. It should be pointed out that peak exposures to SO_2 occurred in Hazelwood rather than in North Braddock and Liberty Borough where the highest particulate levels occurred.

Existing data on TSP is shown in Table III along with the derived suspended sulfate and suspended nitrate data. When allowance is made for flow rates not meeting the criteria for acceptable data, these results support the COH data. The very high levels of suspended sulfates at the Liberty Borough station should be noted.

It is recognized that these values may not perfectly represent the levels of pollution in the neighborhoods of residence of the school children studied. Children in Port Vue to the north of the Liberty Borough station might not have experienced pollution levels quite as high as those experienced by children in Liberty Borough. Because of the topographic complexity of the area, however, some children in the Glassport and Braddock areas may have been exposed to pollution levels higher than those measured at the Glassport and North Braddock stations.

A more detailed description of air pollution levels during this episode will be available.[8]

Results and Discussion

For each school Table IV presents the daily mean $FEV_{.75}$ and FVC values. The results are more easily interpreted by reference to Figure 2 which presents these values graphically and adjusts for differences in school means.

The results are clear: there is no indication of consistent increases in pulmonary function values with time in the more polluted areas. Most frequently a slight downward trend in lung function values is seen. However, the only certain conclusion to be drawn is that the variability of the results over the weekend is much greater than on school days. This unexpected finding will be investigated in more detail in the final analysis.

It must be concluded that gross impairment of lung function, sufficiently severe for that lung function to require several days to recover, did not occur, at least not in a sufficient number of children that the effect could be detected in these primary school study groups as a whole.

The implications of this conclusion are extremely limited. Even severe viral respiratory illnesses, such as influenza, may have a measurable effect only on diffusing capacities and tests of peripheral airways disease and not on forced expiratory volumes.[9] That five weeks may be required for resolution of these aberrations has been suggested.[10] Certain agents, such as coal dust, may have an effect followed by recovery within 24 hr.[11] There does exist one effect, described by Bouhuys,[12] which requires about 72 hr for recovery: the effect of cotton dust on a previously unexposed subject. Knowledge of the types of agents and their concentrations which would produce an effect of the type this study could have detected is almost completely lacking.

Small permanent effects on lung function could not be detected by this study; that would require observations prior to the episode. Effects reversed in less than 48 hr would be either undetected or unproven. Numerous other reasonable hypotheses exist which were not considered, for example that the air pollution episode impaired resistance to acute respiratory infections.

However limited the scientific results of the study, a number of practical lessons were learned. First, in the circumstances of an air pollution emergency only one or two out of dozens of reasonable hypotheses can be tested; the choice will be determined by the experience of the investigator, the amount of time he has to prepare, and the equipment and personnel available. Only within those constraints will the subjective likelihood of positive results affect the choice of studies. Despite the fact that the results from any one study are quite likely to be negative, the investigator must plan to announce the results publicly. As a public health professional he has no choice: the data were collected during a public health emergency from a public concerned about their own family's health.

A second conclusion is that a detailed study design is necessary if one is to have any confidence in results of an episode

Table III. Levels of total suspended particulates, suspended sulfates, and suspended nitrates ($\mu g/m^3$) in Allegheny Co., PA, 17–26 November 1975.[a]

	November									
	17th	18th	19th	20th	21st	22nd	23rd	24th	25th	26th
Total suspended particulates										
Hazelwood	126		305[b]		65	66	94			100
Braddock (North Braddock)	350		476	278	70	61				97
Port Vue (Liberty Borough)	462	569[b]	770[b,c]	408[b]	57	41	294			151
Suspended sulfates										
Hazelwood	12		34							
Braddock (North Braddock)	33		58	26						
Port Vue (Liberty Borough)		91[b]	191[b,d]	90[b]	13					
Suspended nitrates										
Hazelwood	2		7							
Braddock (North Braddock)	5	0	12	6						
Port Vue (Liberty Borough)		10[b]	6[b,e]	3[b]						

[a] No values available for the stagnation advisory period for New Kensington (Logans Ferry), Emsworth (Bellevue), or for Glassport.
[b] Hi-vol data weak, do not meet flow or duration criteria.
[c] Time-weighted average of two values: 929 $\mu g/m^3$ from 0000 to 1500 hr, 458 $\mu g/m^3$ from 1550 to 2330 hr.
[d] 266 and 43 $\mu g/m^3$ (times as in footnote c).
[e] 7 and 5 $\mu g/m^3$ (times as in footnote c).

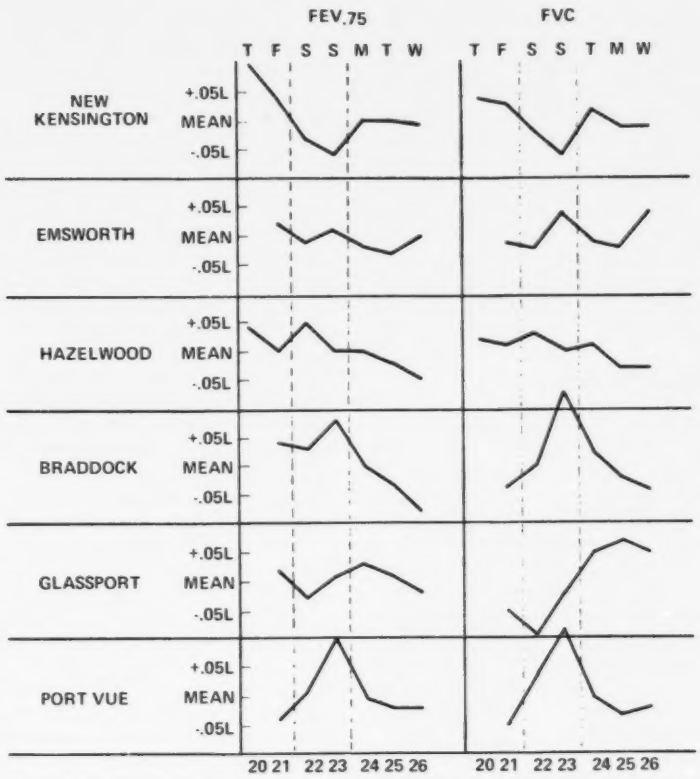

Figure 2. Deviations from mean pulmonary function values by date, adjusted for reporting.

study. In the present study 6 schools were barely adequate; had positive results been obtained, one or two additional control schools from indisputably low pollution areas would have been highly desirable. Certainly a study carried out in just one or two schools could have been highly misleading: that would be the equivalent of selecting one or two pairs of graphs out of Figure 2 at random for interpretation, obviously a hazardous procedure.

A third conclusion is that one may not be able to study the health effects of an episode on the population at the most severely afflicted site, and that if one can the results will most likely be equivocal. This follows from the second conclusion above, that a detailed study design is necessary, and from the restricted spatial, as well as temporal, dimensions of episodes. Only a small fraction of the population is exposed to the very worst of an episode.

The only emergency levels recorded during this episode were, in fact, recorded at a Liberty Borough public high school. The obvious study was not possible, however, since permission could not be obtained in time to study an adequate number of public high schools because of the large number of school boards in Allegheny County. Results from one school would not have been scientifically interpretable. Had blanket permission to study high schools in Allegheny County been obtainable, and that study carried out, there would still remain a large element of uncertainty in the interpretation of results from the one high school in Liberty Borough.

The last conclusion is subjective, and relates to the concern of the people of Pittsburgh concerning the health effects of the episode. Principals and teachers when first approached commonly expressed reservations concerning the potential reaction of parents to the study, because of the economic dependence, direct or indirect, of the majority of the parents upon heavy industry. These reservations were uniformly unfounded: only one expressed refusal by a parent is known. Many parents visited the testing stations on Saturday and Sunday and expressed their interest in the study. Most crucially, the response rates on weekend days of 65 to 80% were much higher than expected (of the two exceptions, one occurred in a geographically extensive parish, the second in a socially changing neighborhood where low response rates for girls were responsible). Subjective expectations of the school personnel and of the investigators was that 40 to 50% response might be expected. In any case, it was clear that parents did not extensively discourage cooperation over the weekend.

A much more detailed analysis of the data collected is currently being carried out, some relating to questions other than the effects of pollution. In particular a search will be made for definable subgroups in these student populations who may have been affected during the episode. The conclusions presented above regarding the health effects of the episode upon the student bodies as a whole would not be invalidated by such findings.

Table IV. Three-quarter second forced expiratory volumes and forced vital capacities by date immediately following the Pittsburgh air pollution episode.[a]

		Thurs. Nov. 20	Fri. Nov. 21	Sat. Nov. 22	Sun. Nov. 23	Mon. Nov. 24	Tues. Nov. 25	Wed. Nov. 26
New Kensington	$FEV_{.75}$	1.80	1.74	1.67	1.64	1.70	1.70	1.69
	FVC	*1.89*	*1.88*	*1.83*	*1.79*	*1.87*	*1.84*	*1.84*
Emsworth	$FEV_{.75}$		1.72	1.69	1.71	1.68	1.67	1.70
	FVC		*1.86*	*1.85*	*1.91*	*1.86*	*1.85*	*1.91*
Hazelwood	$FEV_{.75}$	1.62	1.58	1.63	1.58	1.58	1.56	1.53
	FVC	*1.95*	*1.94*	*1.96*	*1.93*	*1.94*	*1.90*	*1.90*
Braddock	$FEV_{.75}$		1.79	1.78	1.83	1.75	1.72	1.67
	FVC		*2.10*	*2.14*	*2.27*	*2.16*	*2.12*	*2.10*
Glassport	$FEV_{.75}$		1.84	1.79	1.83	1.85	1.83	1.80
	FVC		*1.96*	*1.91*	*1.99*	*2.06*	*2.08*	*2.06*
Port Vue	$FEV_{.75}$		1.77	1.82	1.91	1.81	1.79	1.79
	FVC		*1.89*	*1.98*	*2.06*	*1.94*	*1.91*	*1.92*

[a] All values adjusted for specific students tested on each day.

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The Pittsburgh Air Pollution Episode . . .

. . . was also the subject of a paper presented to the Conference on Environmental Modeling and Simulation (Environmental Research Center, Cincinnati, April 19–21, 1976) in which four U.S. Environmental Protection Agency investigators reported "at least 14 excess deaths" in Allegheny County during the four-day episode in November 1975.

In the paper "Mortality Models: A Policy Tool," Dr. Wilson B. Riggan and his team* state that "In this preliminary study we found 16 deaths when the episode period was compared to the same four days of the week before, and the same four days of the week following the episode. Estimated excess deaths of 23 were found when the period of the episode was compared to the same month and period in the years 1962 through 1972. However, after fitting the model which accounted for temperature and other covariates, we found only 14 deaths."

The investigators used three major sources of mortality data: National Center for Health Statistics, State of Pennsylvania Department of Vital Statistics, and Allegheny County Health Department. The National Oceanic and Atmospheric Administration supplied the meteorological data. Aerometric data were supplied by the Allegheny County Air Pollution Control Board.

"Daily mortality models are useful," said Dr. Riggan, "in that they enable authorities to forecast the probable effect of a specific control action and later to assess the effectiveness of controls. Although man reacts to pollution through a full spectrum of biological responses ranging from subtle physiologic changes to death, mortality is currently the best documented and defined health indicator available."

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